Water, energy and feed resource efficiency

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***Abstract*—Resource efficiency in aquaponics cannot be established from a single production measure. Water reuse, feed input and the supply of nutrients to plants are connected, but each describes a different aspect of system performance. An aquaponics experiment relates feeding conditions to fish feed-conversion ratio, lettuce production, water chemistry and solids output, while a review identifies freshwater inputs, discharge, fish, plant sizing and feeding intensity as context-dependent influences on resource use. Together, these sources support a causal account of how feeding and system configuration can affect production and management requirements. They do not, however, quantify water-use or energy efficiency, nor establish that one aquaponic configuration is consistently superior. This paper distinguishes observed production responses from resource-efficiency claims and examines the measurements needed to connect them. Its central conclusion is that feed efficiency must be interpreted alongside plant output and water quality, water reuse must be assessed alongside freshwater input and discharge, and energy efficiency remains unresolved within the available evidence. Comparative resource claims require measurements of inputs and useful outputs under clearly specified operating conditions.**

I. Introduction

Feed is both an input to fish production and a contributor to the conditions under which plants grow in aquaponics. An experiment relating feeding conditions to fish feed-conversion ratio, lettuce production, water chemistry and solids output shows why a change in feed input cannot be judged by fish production alone [1]. A feeding condition associated with a desirable production response may also change the quantity of solids requiring management. These linked responses make feed resource efficiency a question about the relationship between input, useful production and system condition, rather than a synonym for a favourable result in any one measure.

Water resource efficiency presents a related but distinct problem. A review of aquaponic configurations discusses water reuse, freshwater inputs and discharge together with fish, plant sizing, feeding intensity and nutrient supply [2]. Reusing water describes a system process, whereas an efficiency claim requires attention to the water entering and leaving the system and to the production obtained. The review does not establish a consistent resource advantage for one configuration [2]. Consequently, neither the presence of water reuse nor a configuration label is sufficient evidence for a general claim that less water is needed to produce a given output.

Energy must remain part of the resource-efficiency question even though the available evidence does not resolve it. The feeding experiment does not quantify energy efficiency, and the configuration review provides no direct energy-efficiency evidence [1], [2]. Fish feed-conversion ratio, plant production and water chemistry therefore cannot be used as substitutes for measured energy input. This paper first defines the boundaries of the three resource questions, then explains the supported connections between feeding, nutrient supply and water management. It subsequently compares what the two sources establish with what remains unmeasured, before considering the requirements for defensible assessments of water, energy and feed efficiency.

II. Background and Scope

The available studies approach resource use at different levels. The feeding experiment examines responses associated with feed input, including fish feed-conversion ratio, lettuce production, water chemistry and solids output [1]. The review considers how water reuse, freshwater input, discharge, fish, plant sizing and feeding intensity bear on aquaponic resource use across configurations [2]. The experiment supplies a specific example of interacting production and management responses; the review places such responses within a broader account of system choices. Neither contribution should be read as a complete accounting of water, energy and feed efficiency. Their value here is to identify relationships that an efficiency assessment must keep visible.

Comparing the two approaches clarifies why production performance and resource efficiency are not interchangeable. Fish feed-conversion ratio concerns the relationship between feed and fish production, while the experiment also reports plant production and changes in water chemistry and solids output [1]. The review identifies feeding intensity and nutrient supply as influences that depend on fish, plant sizing and configuration [2]. Taken together, these observations indicate that a feeding decision can have consequences beyond the fish response. They do not establish that increasing or decreasing feed will improve overall resource efficiency, because the relevant outputs and resource flows have not all been evaluated together.

The scope of this synthesis is therefore explanatory rather than comparative ranking. For water, the supported questions concern reuse, freshwater input and discharge, not a demonstrated numerical saving [2]. For feed, the supported questions concern the association of feeding conditions with fish, lettuce, water-chemistry and solids responses [1]. For energy, neither source supplies a direct efficiency comparison [1], [2]. This boundary matters: a claim about one measured response cannot be extended to an unmeasured resource without further evidence. The remaining gap is an assessment that relates clearly

defined resource inputs to useful outputs while accounting for the accompanying system responses.

III. Core Concepts and Mechanisms

Feed resource efficiency begins with the distinction between feed supplied and production obtained. Fish feed-conversion ratio addresses one part of that relationship, but the feeding experiment also connects its feeding conditions to lettuce production, water chemistry and solids output [1]. The review identifies feeding intensity and nutrient supply as related influences within systems whose fish and plant components may be sized differently [2]. These findings support a causal interpretation in which changing feed affects more than the fish production measure being assessed. They do not specify a universally efficient feeding level: an interpretation of feed efficiency must also consider the plant response and the management implications of changed water chemistry and solids.

Water reuse has a narrower meaning than water-use efficiency. Reuse concerns the continued use of water within an aquaponic arrangement; an efficiency judgement also depends on freshwater input, discharge and the output used for comparison. The configuration review addresses those water-related factors and treats their effects as dependent on system context [2]. Feeding adds another connection because the experiment associates feeding conditions with water chemistry and solids output [1]. Those observations make water condition relevant to interpreting resource use, but they do not quantify water saved or show how much freshwater a feeding change requires. Reuse should therefore be reported as a process unless measured inputs and outputs support a stronger efficiency claim.

Energy efficiency requires its own input and output relationship rather than an inference from feed or water results. Neither the feeding experiment nor the configuration review directly measures the energy-efficiency outcome needed for such a comparison [1], [2]. A system might show a favourable fish feed-conversion ratio, plant response or pattern of water reuse without those observations revealing energy use per useful output. This is a limit on the interpretation of the evidence, not a finding that energy use is unimportant or that particular configurations perform alike. The appropriate mechanism-level conclusion is that feed, water and energy questions are connected in a system assessment but cannot be answered by the same indicator.

IV. Evidence Synthesis

The strongest direct production evidence concerns the consequences of changing feeding conditions. The experiment relates feed input to fish feed-conversion ratio, lettuce production, water chemistry and solids output [1]. Its contribution is the simultaneous visibility of productive responses and management-relevant responses, which prevents an account based solely on feed supplied or fish produced. A key limitation is that feed quantity and feeding frequency changed together [1]. Their separate effects cannot therefore be attributed from this experiment alone. Nor can its reported responses establish water-use or energy efficiency, because those efficiencies were not quantified. It supports a connected interpretation of feed-related outcomes, not a complete resource balance.

The review extends that interpretation by showing which system relationships matter when water and nutrient use are considered together. It discusses water reuse alongside freshwater inputs and discharge, and relates feeding intensity and nutrient supply to fish, plant sizing [2]. This wider framing helps explain why a feed response observed in one arrangement should not automatically be generalised across arrangements with different component proportions. At the same time, the review does not demonstrate a consistent advantage for a particular configuration [2]. It provides grounds for identifying potentially consequential conditions, but not for declaring that any one arrangement is universally more efficient in water, feed or energy terms.

Read together, the sources support a conditional account rather than a single ranking. The experiment shows that feeding conditions are associated with multiple fish, plant and water-related responses [1]; the review indicates that freshwater flows, discharge, feeding intensity and fish, plant sizing are relevant to resource use in context [2]. Thus an apparent gain in one output must be interpreted against the inputs and other responses that accompany it. This synthesis does not establish whether a particular change produces a net efficiency gain. It identifies the comparison that would be required: the same defined resource input and useful output must be tracked across the conditions being judged.

The gap is most pronounced for energy. Neither source provides direct evidence that would place energy input beside the production responses or water flows under discussion [1], [2]. As a result, the supported relationships between feeding, plant production and water management cannot be converted into an energy-efficiency result. The evidence is also insufficient for a combined numerical statement about all three resources. Keeping these limits explicit preserves the useful causal insights in the available work without treating an unmeasured resource as though it had been evaluated. It also distinguishes a plausible basis for future comparison from a demonstrated comparative outcome.

V. Practical Implications and Limitations

A practical feed assessment should retain the distinctions made visible by the experiment. Fish feed-conversion ratio indicates a fish-related response to the feeding conditions studied, while lettuce production, water chemistry and solids output show why that response cannot stand alone [1]. Considering these observations together can identify whether a production gain is accompanied by a change requiring attention elsewhere in the system. It cannot, on this evidence, identify the independent effect of feed quantity rather than feeding frequency, because both changed together [1]. A more discriminating comparison would separate those changes before attributing a particular response to either one.

For water, the immediate implication is to specify what is meant by efficiency before comparing systems. The review

addresses reuse, freshwater inputs and discharge as distinct considerations and does not find a consistent configuration advantage [2]. Reporting reuse alone would leave unresolved how much freshwater entered, how much water left and what production accompanied those flows. Fish, plant sizing and feeding intensity also need to be stated when interpreting a comparison, because the review identifies them as context-dependent influences on nutrient supply and resource use [2]. The evidence supports careful definition of a comparison, not a universal water-saving figure or an unqualified preference for one configuration.

Energy-efficiency claims require particular restraint. The available experiment does not quantify energy efficiency, and the review offers no direct energy-efficiency evidence [1], [2]. Neither source can establish whether a feeding condition or configuration uses less energy for a specified output. The highest-value validation step is to measure energy inputs alongside the production and resource-flow measures already identified, under operating conditions described well enough to interpret differences. Comparable assessment of feed and water would also require specified feeding conditions, freshwater inputs, discharge and useful outputs [1], [2]. Until such measurements are available, energy remains an explicit evidence gap rather than an inferred benefit.

VI. Conclusion

Water, energy and feed resource efficiency are related questions, but the available evidence answers them to different degrees. The feeding experiment connects feed input with fish feed-conversion ratio, lettuce production, water chemistry and solids output [1]. The review places water reuse alongside freshwater input and discharge and identifies fish, plant sizing and feeding intensity as relevant contextual influences [2]. These contributions explain why a productive feeding response or the practice of water reuse is not, by itself, proof of overall efficiency. They provide no direct energy-efficiency result and no consistent configuration ranking [1], [2].

A defensible next comparison would define useful outputs and measure feed, freshwater input, discharge and energy input under specified feeding conditions and system arrangements. It would distinguish the effects of feed quantity and feeding frequency, which the available experiment changed together, and would assess configuration claims without assuming a general advantage that the review does not establish [1], [2]. Until that evidence exists, the sound conclusion is conditional: feeding and system choices can affect several production and resource-related responses, but measured inputs and outputs are needed to determine whether those changes constitute water, energy or feed efficiency gains.

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References

[1] R. Subramanian, C. S. Nair, R. Manoharan, D. Nishanth, E. El-Haroun, and A. Jaleel, "Integrated nutrient and feeding optimization strategies in aquaponics for sustainable urban food production and water conservation," *Frontiers in Sustainable Food Systems*, 2025.

[2] V. Lobanov, H. Monsees, F. Latrille, G. Pate, and A. Joyce, "Coupled vs. decoupled aquaponics: Evidence, mechanisms, and methodological gaps in the productivity hypothesis," *Aquacultural Engineering*, 2026.